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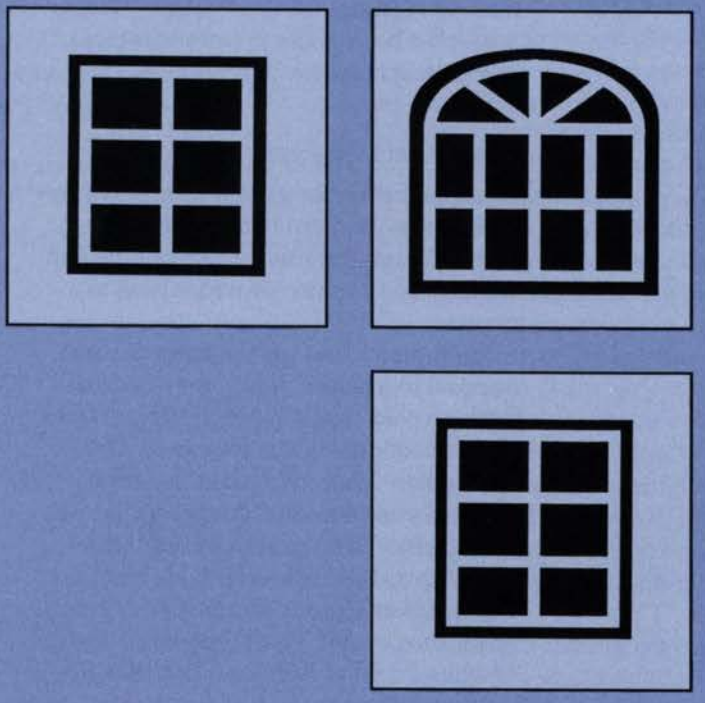
Insulating Windows and Screens



Council Notes **Volume 13, Number 4**
Building Research Council College of Fine and Applied Arts – University of Illinois

Making the right choices when selecting your windows and screens will brighten your energy efficiency outlook.

If you're wondering what type of window system to purchase for a new home, or how to increase the energy-efficiency of your existing windows, this booklet will answer your important questions about double-pane, triple-pane and storm windows, and explain how to select and install the right window screens for your particular needs.

HEAT LOSS/GAIN

In most homes, the greatest heat loss and gain occurs through windows and doors.

Terms and Concepts

Heat can be lost or gained in four ways.

Radiation. Radiant heat is the warmth you feel from the sun. Heat from the sun shining into a house provides heat to a room.

Conduction. Heat gained from the sun, trapped in a closed space, may be lost through cold windows and wall surfaces by conduction. Heat is transferred by conduction when two materials touch. When warm room air touches a cold window surface, heat moves through the glass toward the colder outside air.

Convection. Convection transfers heat by air movement. When heated room air touches a cold window surface, the air temperature near the window drops and the cooled air sinks, creating a draft in the room.

Infiltration. Infiltration occurs when unwanted cold or hot air enters the living space through cracks or other openings. This happens when windows do not seal tightly, or when there are uninsulated gaps between the window unit and house frame.

Problems and Solutions

Sometimes windows do not adequately shield occupants from the outdoor air temperature.

This happens when you and others feel:

- ▲ cold blasts of air from your windows,
- ▲ drafts flowing down cold glass surfaces,
- ▲ chilled when sitting near large windows,
- ▲ extreme dryness in winter, and
- ▲ discomfort, even when the thermostat is set high enough to warm your living space.

Reducing air leakage around windows and increasing the thermal resistance of these openings will help take care of these problems.

You can do this by:

- ▲ ordering energy-efficient windows for a new home,
- ▲ repairing and tightening existing windows,
- ▲ using storm windows, or
- ▲ installing energy efficient replacement windows.

THERMAL PERFORMANCE

Thermal performance means how well heat loss or gain is controlled by windows, walls, insulation, or even clothing. The term R-value is often used to describe insulation, but it can be applied to the thermal performance of windows. R-value is a measure of resistance to heat flow.

The larger the R-value, the better the insulating properties of the material. The R-value of a single-pane window is close to 1.0. **Table 1** shows approximate R-values for common windows.

Window manufacturers also use U-values to describe performance. While the R-value describes the thermal resistance of a material, the U-value describes its thermal conductance. These terms are related, U=1/R, which means that a window with an R-value of 2 will have a U-value of 0.5. The lower the U-value, the lower its ability to conduct heat, and the better the window.

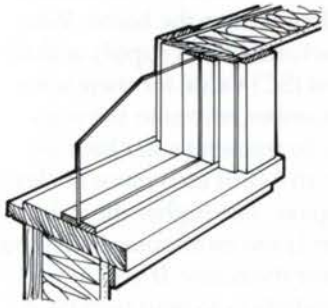
The National Fenestration Rating Council (NFRC) has developed voluntary standards to measure and report window thermal efficiencies. The efficiency ratings are listed on a label that is affixed to the window so that consumers may compare ratings. The ratings are also listed in the *Certified Products Directory*, published by the NFRC. Unless the window has been rated by this agency, there is no guarantee that the values reported by a manufacturer are valid for comparison purposes, as the manufacturer may use different testing methods.

The information contained in this publication was produced by the School of Architecture—Building Research Council (BRC) at the University of Illinois at Urbana-Champaign. For more information, or a free publications catalog, call 217-333-1801.

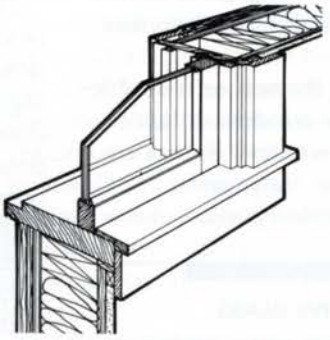
Table 1
R-Value of Movable Sash (Wood Frame)

Glazing	R-Value
Single Glazing	1.06
Double Glazing	
prime (sealed glass, 1/2" air space)	2.08
prime (single-pane) + storm	2.08
prime (wave-length-selective sealed film or glass, 1/2" argon gas-filled)	2.56
Triple Glazing	
prime (sealed glass, 1/2" air space) + storm	2.63
triple-pane (sealed glass, 1/2" air space)	2.63
triple-pane (sealed glass, wave-length-selective film or glass, 1/2" argon gas-filled)	3.7

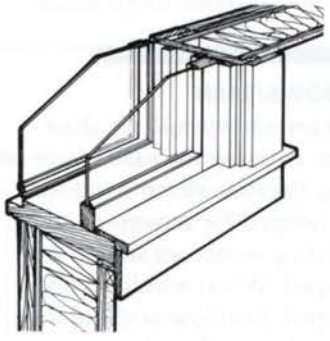
The R-values for actual windows may vary due to glass thickness, frame type, and type and emissivity of wave-length-selective coatings. Source: 1993 A.S.H.R.A.E. Fundamentals.



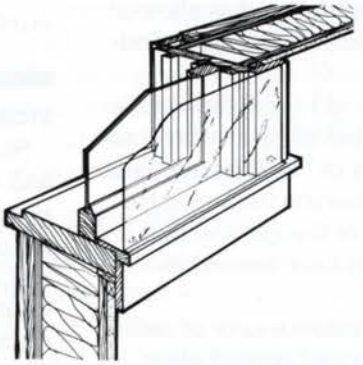
A single-pane window has an R-value of 1. Compared to the insulated wall below it, the window is a big energy loser.



The thermal efficiency of the window can be improved by replacing the single-pane unit with a double-pane window.



By installing a storm window on the outside, the R-value of the window increases to about 2.



An inside storm window is just as effective as an outside storm window. An inside storm window can be used to provide a third pane on double-glazed windows.

TRIPLE- AND DOUBLE-GLAZED WINDOWS

Insulated windows are recommended for areas where the average January temperature is 45°F or colder and where summer air conditioning is required. After caulking and weatherstripping, improving the thermal performance of single-pane windows is the best way to weatherize a home.

Properties and Advantages

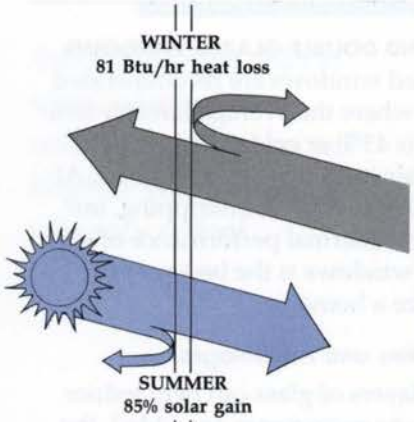
Adding layers of glass can help reduce heat loss. As more panes are added, the R-value increases. Double glazing cuts heat loss almost in half and triple glazing cuts heat loss by two-thirds, but reduces light transmission by about ten percent.

Effectiveness of double-pane and triple-pane windows is mostly due to the insulating effect of the enclosed air spaces, rather than extra layers of glass. The R-value for an enclosed air space gradually increases as the air space is enlarged and reaches a maximum value of about R-1 when the air space is 3/4" to 3". R-value then decreases again due to convection between the panes of glass. By enclosing a gas, such as argon or krypton, between layers, window R-values can approach R-4.

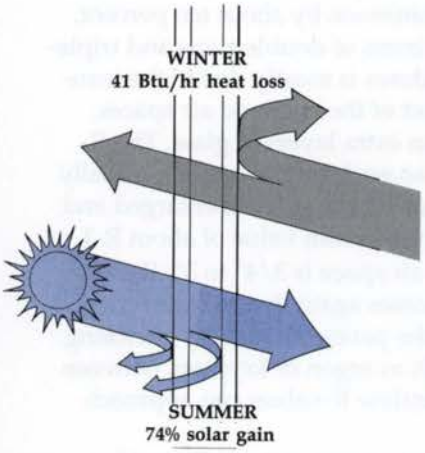
Double glazing may be achieved by placing a storm window over the single-pane window on the outside of the house, or by replacing a single-pane window with an insulated window, consisting of two layers of glass sealed at the edges and separated by a space. The enclosed space is usually less than 1/2".

You may also double-glaze by applying on the inside of the single-pane window a separate glass and sash—sash refers to the framing in which a pane is set and is used to describe the pane and framing together as well. The R-value of double glazing is the same if a plastic film or a plastic sheet is used in place of glass.

Storm windows may be used to improve the energy efficiency of single- or double-pane windows. Triple-glazed windows may be either factory-sealed triple units or double-glass sealed units with storm windows.



Single-pane glass is not effective in preventing heat loss in winter and heat gain in summer.



Double-pane glass provides an approximate 50% improvement in winter heat loss when compared to single-pane windows. Summer heat gain is slightly reduced.

Wave-length-selective double-pane glass, or coated polyester film, cuts summer heat gain and winter heat loss dramatically.

Sealed Glass

New insulated windows use sealed glass. Sealed glass can be installed in an operating sash—a sash that allows you to open and close the windows—or set in the frame of a fixed window.

Most operating windows can be purchased with double or triple glazing. Sealed-glass windows offer a number of advantages to the home owner.

Sealed-glass windows do not have to be put up and taken down with changing seasons. Because the sheets of glass are sealed, only two surfaces need to be washed. Moisture and dust cannot get into the air space between panes of glass when the edges of the glass are properly sealed at the factory. (During the sealing process, the air between panes is dried so that no moisture can condense on the inside surfaces of the glass. Many manufacturers enclose moisture-absorbing granules between the panes of glass to ensure dryness.) Sealed glass does not interfere with ventilation.

It is estimated that the seal on a double- or triple-pane factory window will last 10 to 20 years. If the window frames are still in good condition, they can be reglazed with new sealed glass.

WAVE-LENGTH-SELECTIVE GLASS

Sealed window units featuring wave-length-selective glass improve the thermal performance of windows without adding extra panes of glass. **Table 1** shows comparative R-values for regular and specially treated sealed glass windows. This new technology has allowed the R-values of window glazing to double or quadruple.

The introduction of Low-E (low-emissivity) sprayed or baked on coatings, suspended plastic film or "heat mirror" and surface-applied films has increased the thermal resistance of the glass so that it reflects radiant heat back toward its source.

The sun is the greatest source of radiant heat in summer and treated glass may reduce your air-conditioning needs by reflecting summer heat from the rooms inside. In winter, when the furnace provides heat that radiates toward the exterior windows and walls, this glass will reflect it back into the room, helping you reduce winter fuel costs.

Two types of wave-length-selective glass are available. Low emissivity glass fuses a metallic oxide to the interior surface of one pane of glass in a sealed window unit. Another glass product deposits a microscopic layer of metallic oxide on a polyester film stretched between the panes in a sealed glass unit.

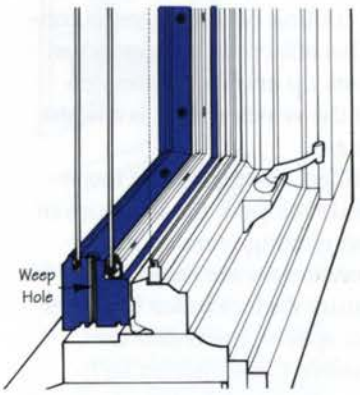
Several of the same benefits of wave-length-selective glass can be achieved by using films that home owners can install, which adhere to window glass or are installed on the window frame using a base and spline. Films that adhere to the glass should not be used on sealed double- and triple-pane windows (most manufacturers will not honor their warranty if these films have been applied by the consumer), but they can be very effective on single-pane windows.

These coatings will affect the amount of visible light entering the home. Window manufacturers often supply a shading coefficient (SC) value for their windows. This number relates to the window's ability to transmit solar heat as compared to an 1/8th inch piece of clear single pane glass. The higher the value (between 0 to 1) the more solar heat (and light) can enter the home. If you intend to use solar radiation to help heat your home in the winter (northern climates), look for a window that has a high SC value. If you are concerned about the possibility of your home over-heating in the summer (southern climates), look for a window with a SC value that is a low number as it will provide more shade.

STORM WINDOWS/SASH

Storm windows keep cold air, dust, and soot from entering the sash of operating windows. Because storm windows are often exchanged for screens in summer, all operating windows should be weatherstripped. When windows are weatherstripped, heat loss is about the same for a window with a storm window as it is for double-pane glass.

To reduce the likelihood of moisture condensation occurring between the panes, the inside window must fit more



Some window units, including those with built-in blinds, use removable storm panels. Weep holes in the window frame must be kept open or condensation may occur.

tightly than the outside window. Storm windows installed on the inside should be weatherstripped. Those on the outside should fit rather loosely and the inner window sash should be weatherstripped. If the storm window fits tightly, drill three 1/4-inch vent holes in its frame so that outside air can circulate between the glass and reduce the possibility of condensation between the inside and outside sash. These "weep" holes must be cleaned regularly.

Combination Windows

A double- or triple-track combination screen and storm window is the most popular insulating unit for older, double-hung windows. These windows usually have one screen panel and two glass panels that can be moved up and down in tracks on the window frame.

Double-track windows. A double-track unit has a storm panel, which is a pane of glass set in a narrow frame clipped to either the outside or the inside of a window sash, and a screen in one track. In the second track system, there is a second glass panel that can be raised to permit ventilation through the screen or lowered for insulating purposes.

Triple-track windows. In the triple-track system, each panel rides in its own track and the screen can be removed independently.

Combination windows. Combination windows may be custom-made to fit the measurements of any window opening. Their frames are usually low-maintenance, aluminum-mill finished or factory painted. The major advantage to combination systems is that the storm windows and screen can be inserted or removed from inside the house. Even in the interests of saving energy, you should never caulk the bottom edge of a combination storm-screen window.

Inside Storm Windows

Inside storm windows can be used, as other storm windows, to add a second or third layer of glazing to an existing window. They can be made of glass, but acrylic panels are more common because they are lighter, which makes seasonal installation and removal easier and safer. A special cleaner must be used with a soft cloth to prolong the life of acrylic panels.

Inside storm windows often have a magnetic strip around the edge of the panel. This attaches to a thin, metallic tape permanently mounted to the window frame. This tape is not usually noticeable. The prime window should be fairly tight if magnetic attachment is used, or wind pressure blowing through cracks may blow off the inside storm window. Some inside storm windows are held in place with clips.

Installing inside storm windows is often the only way to improve thermal performance without replacing the entire window. Windows with magnetic edges will stick to steel frames; however, the steel conducts heat to the outdoors and condensation may occur on the frame. The primary disadvantage of inside storm windows is that they must be stored when not in use.

Temporary Storm Windows

Although the various types of storm panels previously described are the most satisfactory, temporary protection can be provided at considerably less cost using various plastic materials.

Polyethylene. The least expensive material is polyethylene, which is frosted but translucent. Because polyethylene is damaged by sunlight, it is good for only one year.

Vinyl. Vinyl, which is clear, distorts images slightly, but may last three to five years.

Flexible polyester glazing (FPG). This is the best material, but it is the most expensive film available. FPG comes in various thicknesses, the thicker films having longer lives.

These films can be attached either to the exterior or interior of window frames. Exterior installation using batten strips is common. The film may be used to cover wood screen frames if there are screens but no storm windows.

Many films are available in kit form, made for easy home owner installation. Kits include instructions, film, splines and adhesive-backed mounting strips, which may remain in place if you are using one of the several films that can be removed and reinstalled. Other films re-

quire heat to shrink-fit them and can be left in place in summer to help reduce the cooling load.

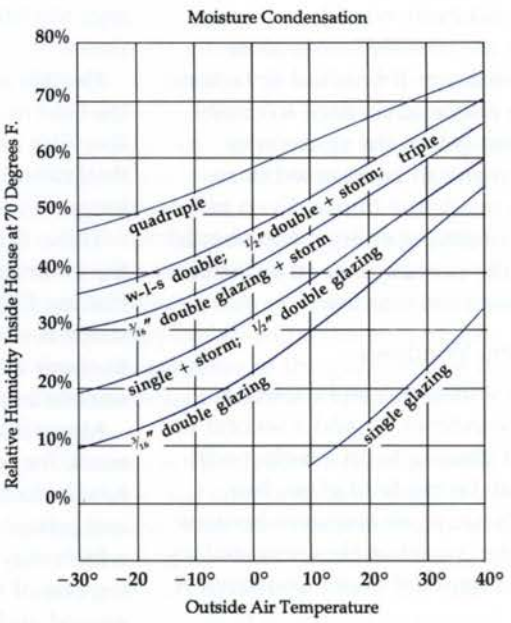
STORM PANELS

As described, sometimes the second or third pane of glass is provided by a storm panel. Panels can be used only on windows that have special hardware or a groove into which the panels can be fitted. Panels are not commonly available for double-hung windows.

Unlike storm windows, panels move with the operating window, and do not interfere with window operation or ventilation.

Panels can be applied on the inside or outside of the window sash. Inside panels are more convenient, but outside installation reduces moisture condensation on the existing window. Inside storm panels should have either a rubber gasket or spring-metal weatherstripping around their edges to create a good seal.

Windows with narrow venetian blinds between the panes use inside storm panels in case the blind mechanism breaks. Vents in the sash are provided so that moisture can escape from between the panes of glass. Cleaning the vents with a pipe cleaner should be done on a yearly basis.



The chart shows the point at which condensation occurs on the room-side glass surface for various percentages of indoor humidity and outdoor temperature. The humidity must be kept below this point to avoid condensation on the window.

WINDOW FRAMES

Window framing material affects the energy efficiency of windows by acting as a heat sink, drawing heat away from the glass and cooling off the edges in contact with it. This effect can be seen when a window frosts up and frost forms on the portion of the window that is coldest: the outside edges.

Before gas-filled air spaces and low-e coatings were developed, the R-values of the frames and glazing were about the same. Now consumers are faced with product literature that includes R-values for glazing, air spaces, the entire unit, and its infiltration. Construction techniques vary among manufacturers so that there are no simple rules to follow, but often vinyl will perform better than wood, and wood better than aluminum. Compare the R-values listed and which tests or methods were used to obtain them.

Wood Frames

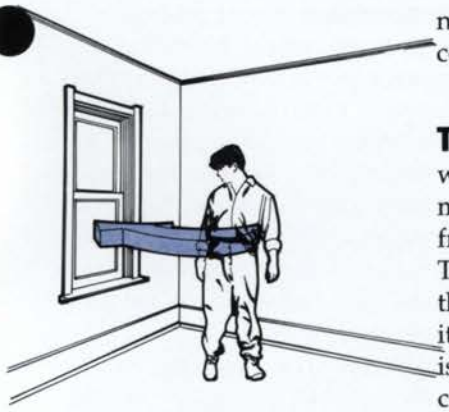
Traditionally wood has been used for the construction of frames. Although wood is still popular, it requires painting on a regular basis. Manufacturers have responded to this by developing clad windows. Cladding means wrapping the exterior portions of the window in either aluminum or vinyl materials which eliminate the need to paint.

Aluminum Frames

Another frame material, aluminum, is used primarily in commercial buildings, or in homes in temperate climates. Aluminum offers low maintenance, light weight/easy operation, and does not swell with changes in humidity. Unfortunately, it is a poor insulator and should not be used for primary windows in a heating climate.

Vinyl Frames

Vinyl is taking over the market previously occupied by aluminum windows. It offers low maintenance, light weight/easy operation, and does not swell with changes in humidity. Although it was introduced primarily as a replacement option, improvements in construction and quality have allowed vi-



When our bodies radiate heat to cold surfaces, we feel chilled. This is why raising the inside glass surface temperature can help us feel more comfortable.

Cold window glass causes heated air to cascade down with considerable velocity. The cooled air fans out across the room when it hits the floor.

nyl windows to gain acceptance for new construction.

Wood-Composite Frames

The newest type of frame is made from a wood-composite material, which looks much like wood, but is actually made from wood fibers and resin by-products. This process results in a higher R-value than that of wood and dimensional stability. Wood-composite frames are prefinished so painting is not a maintenance concern.

COMFORT AND ENERGY SAVINGS

When multiple glazing is installed correctly, your comfort and energy savings will both increase.

Comfort

The greatest improvement when multiple glazing is installed is the reduction of cold drafts at ankle level. The air layer near the floor seems warmer. This improvement in comfort results from the change in surface temperature of the glass that faces the occupants. For example, on a day when the outdoor air temperature is 0°F and the indoor air temperature is 70°F, the inside surface of the glass is about 17°F to 23°F depending on the window construction. This cold surface results in a large heat loss by radiation from the occupant to the cold glass. See **Table 2**.

Table 2
Glass Temperature
(0° outdoor temperature, 70° indoor temperature)

Glazing	Temperature, F
Single Glazing	17°
Double Glazing	
prime (3/16" sealed glass)	33°
prime (1/2" sealed glass)	46°
prime (single-pane) + storm	46°
prime (wave-length-selective glass, 1/2")	55°
Triple Glazing	
prime (3/16" sealed glass) + storm	52°
prime (1/2" sealed glass) + storm	55°
sealed triple-pane, 1/2" air space	55°
Quadruple glazing	
prime (sealed triple-pane) + storm	59°

The warm room air meets the cold glass surface, becoming chilled and sinks. This convection flow of chilled air is much cooler than room air and flows quickly to the floor. Where windows are tall, the flow of air is sufficient to create a splash of cold air on the floor, which then circulates toward the middle of the room.

When storm windows are installed, the inside glass surface temperature increases from about 17°F to about 47°F, or about 30°F warmer than single-pane windows. With triple glazing, the glass surface temperature reaches about 52°F or about 35°F warmer than a single-pane window. With warmer glass surfaces, the radiation heat loss is reduced, and the convection flow is greatly reduced. Multiple glazing also reduces the tendency of water vapor to condense on the glass surface.

If the prime window frames are wood and in reasonably good condition, weatherstripping these windows and adding tight-fitting storm windows is as effective as using double-pane windows to improve room comfort.

Energy Savings

The use of double-pane windows will reduce heat loss through the glass by about one-half. How does this affect the total energy bill? Heat lost through windows is only a portion of total heat loss, which also includes losses through walls, ceilings, foundations, and by infiltration. Even if the heat loss from every window were halved by changing from single glazing to double glazing, the total heat loss of the building would not be cut in half. Actual dollar savings are difficult to predict. The relative cost of fuel varies widely. With more expensive fuels, efforts to conserve heat will have a more rapid payback.

Caulking around the edge of the prime window will make it even more energy efficient. Caulking a wood window in a masonry wall reduces heat loss by 42-75 percent if the window is tight in other respects.

SCREENS

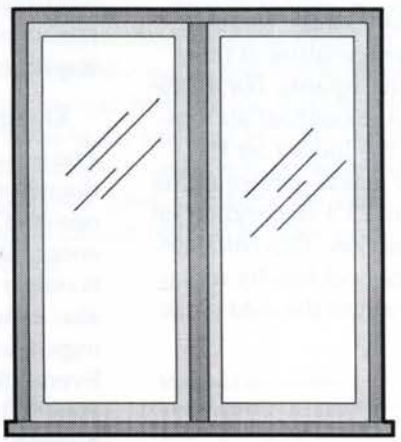
Only the opening portion of a window should be screened. Screening the rest of a window, or a fixed window, is unnecessary. Screens shut out daylight and interfere with the view. Full screens on a double-hung window block out approximately 50 percent of available daylight.

Screens should be made of non-corrosive materials. To keep out insects, 16 mesh screen (256 openings per square inch) is recommended. Aluminum is the most popular screen material, but bronze and fiberglass are also used.

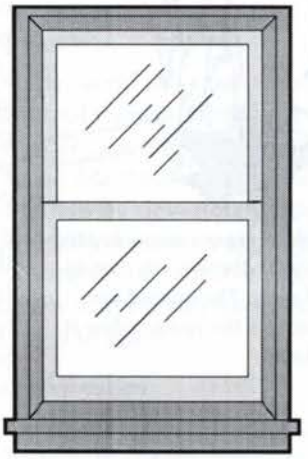
Bronze screens are found on older windows. If these screens are not replaced regularly, the bronze can oxidize, wash down, and stain siding. Fiberglass is transparent, giving a better view to the outdoors, but it can be eaten by pests. When installed over large openings (such as screened patios), fiberglass tends to sag, especially when icy winters are common. A metal screen is a better choice for large screened openings.

To maximize heat gain from the sun on south windows during the heating season, it is essential to be able to easily remove the screens. Screens to reduce heat gain on east and west windows reduce the summer cooling load.

A metal louver-type screening, which reduces the sun load during the cooling season, is suggested for east and west windows having no other type of sunshade. However, such screening interferes with vision. One heat-inhibiting screen is made of an aluminum sheet and has mini-louvers for ventilation. Another product is made of heavy mesh polyester. Both reduce visibility slightly.



Casement Window



Double-Hung Window

Examples of popular window types are the casement window and the double-hung window.

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